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Finance and the Earth system – Exploring the links between financial actors and non-linear changes in the climate system

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ABSTRACT

Financial actors and capital play a key role in extractive economic activities around the world, as well as in current efforts to avoid dangerous climate change. Here, in contrast to standard approaches in finance, sustainability and climate change, we elaborate in what ways financial actors affect key biomes around the world, and through this known "tipping elements" in the Earth system. We combine Earth system and sustainability sciences with corporate finance to develop a methodology that allows us to link financial actors to economic activities modifying biomes of key importance for stabilizing Earth's climate system. Our analysis of key owners of companies operating in the Amazon rainforest (Brazil) and boreal forests (Russia and Canada) identifies a small set of international financial actors with considerable, but as of yet unrealized, globally spanning influence. We denote these "Financial Giants", and elaborate how incentives and disincentives currently influence their potential to bolster or undermine the stability of the Earth's climate system.

1. Introduction

Humans have become the main driving force behind global environmental change at unprecedented scales (Rockström et al., 2009; Steffen et al., 2015; Worm and Paine, 2016). However, not all of the world's regions are affected by, nor affect, the climate system in the same way. A number of specific biomes and biogeophysical processes have been highlighted as exceptionally important for global climate stability due to their ability to affect feedback dynamics in the Earth system (Steffen et al., 2015). These different biomes and Earth system processes have variously been conceptualized as "sleeping giants" in the carbon cycle (Steffen, 2006), "tipping elements" in the Earth system (Lenton et al., 2008), and "planetary-scale tipping points" (Barnosky et al., 2012; Lenton and Williams, 2013). Changes in the stability of tipping elements are increasingly being accounted for in climate models (Cornell et al., 2012), and include, among other things, deforestation (Steffen et al., 2004). Forest biomes are of particular importance as tipping elements because of the nature of their biogeophysical climate feedbacks. Of all the major forests on the planet, the Amazon and the boreal forests are of particular importance; more so than temperate forests and Asian rainforests (Snyder et al., 2004; West et al., 2011; Steffen et al., 2015, see also Supporting Information 1). Their disproportionate influence on climate stability suggests that in order to safeguard a prosperous future for humanity, society needs to consider approaches that, in addition to emission reductions, maintain and enhance resilience of these forested biomes (and other tipping elements) (Schellnhuber et al., 2016; Rockström et al., 2017).

Financial actors, such as international development banks, institutional investors, credit rating agencies and international commercial banks, are increasingly interested in the financial risks of climate change and associated changes in ecosystems. In parallel, scholarly interest in the climate-finance nexus has also increased. This includes work on e.g. "green bonds" and other impact investments, assessment of climate-related financial risk and insurance mechanisms, ESG measures and differential performance of socially responsible investment portfolios, as well as drivers of responsible investment (Collier et al., 2009; Sievänen et al., 2013; Revelli and Viviani, 2015; Müller and Kreuer, 2016; Battiston et al., 2017; OECD, 2017; Scholtens, 2017).

Two gaps emerge in relation to this development, particularly in the finance industry. First, while the growth in the "green bonds" market is

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impressive, it represents only a fraction of global capital flows: less than 0.2% of debt securities issued globally (OECD, 2017 p. 23). Second, avoiding dangerous climate change requires taking account of the non-linear, threshold dynamics encompassed by the tipping elements outlined above (Steffen et al., 2018). However, most current "green" financial initiatives focus primarily on various ways to reduce emissions through e.g. divestment, or renewable energy, energy efficiency and low-carbon transport investments — the latter three together representing 79% of the green bond market (OECD, 2017 p. 25).

Thus, while reduction of greenhouse gas (GHG) emission is crucially important to avoid dangerous climate change, it is not enough (Steffen et al., 2018). Bolstering the capacity of key tipping elements to prevent them from "tipping" is equally essential. Ignoring the non-linear dynamics encompassed by tipping elements could have detrimental effects on the ambitions set by the Paris Agreement, and threaten the achievement of the Sustainable Development Goals (Schellnhuber et al., 2016; Rockström et al., 2017). It also has repercussions for economic stability and financial risk (Lawrence and Vandecar, 2015; Chatterjee et al., 2016; UNEP Inquiry, 2016; Battiston et al., 2017; Scholtens, 2017).

This paper combines Earth system and sustainability science with corporate finance, to explore how the links between financial investment and non-linear climate dynamics can be analyzed. This is not only of interest to policy and financial actors, but also for scholars interested in understanding how key global actors affect the climate system either through their position in global markets (cf. Österblom et al., 2015), or through processes of "telecoupling" (Liu et al., 2015). Telecoupling refers to the connections between geographically separate biomes and economic activities. These global connections between human and natural systems have both socioeconomic and environmental effects (Liu et al., 2015). In the context of finance and the biosphere, such telecoupling emerges from the fact that financial investments and investment policy decisions may have cross-continental social and ecological effects. Documented examples include international investments in companies associated with land use change through e.g. palm oil production in Borneo (WWF and EnviroMarket, 2012), or sustainable investment policies by major pension funds which increase the pressure on corporations to improve their environmental, social and governance performance (Galaz et al., 2015).

We propose a novel methodology to identify the ways in which financial actors and flows of capital are linked to biomes associated with key tipping elements in Earth's climate system and ask:

a) Is it possible to identify a limited set of financial actors mediating flows of capital to known tipping elements in the Earth's climate system?
b) What incentives and mechanisms of influence exists for these actors to alter investments in support of global climate stability?

2. Methods and data

2.1. Selection of cases

A number of regional biomes and associated Earth system processes have been proposed as tipping elements, whose dynamics, if disrupted through multiple feedbacks in the Earth system, could contribute to the destabilization of the global climate system (Lenton et al., 2008 and references therein; Steffen et al., 2018). Here we select two of these known biomes – the Amazon tropical forest in Brazil and the boreal forests in Canada and Russia (Fig. 1). The resilience of these biomes is linked to both climatic and non-climatic anthropogenic drivers, such as deforestation driven by economic activities and their associated financial inputs (see Supporting Information 1 for details and known threshold uncertainties).

As noted earlier, our selection of biomes is based on the strength of biogeophysical feedbacks of these forests to the climate system. As such, the sample provides a strategic first selection to illustrate the strength of the methodology as well as the kind of insights provided. The methodology could also be applied to assess links between financial actors and other critical ecosystem services or "planetary boundaries", such as biodiversity. We leave this for future research.

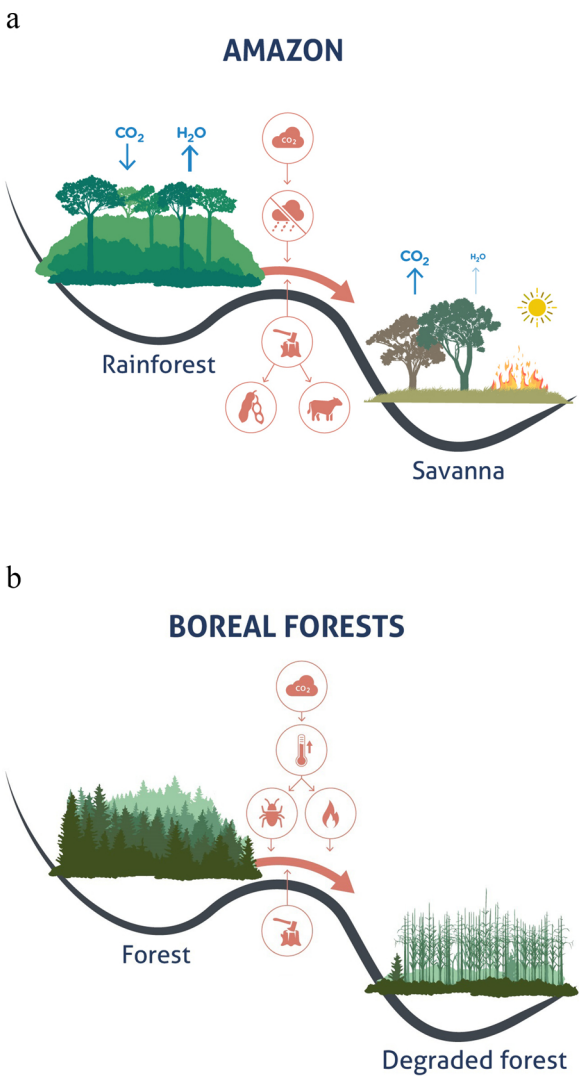

Fig. 1. Threshold dynamics in selected tipping elements.
a. Amazon region. Deforestation in the Amazon region has been a well-known challenge for climate policy for decades. The Amazon biome has been proposed to contain a tipping point beyond which increasing deforestation could lead to an abrupt shift from rainforests to savannas and possibly to the emergence of a semi-desert area (in the driest portion of Northeast Brazil) with detrimental implications for both the regional and global climate. Symbols display main environmental and socio-economic drivers.
b. Boreal forests. The world's forests both dampen or amplify anthropogenic climate change through forest-climate interactions and exchanges of energy, water, and CO_2. Boreal forests play a critical role in the climate system by affecting the surface albedo. It has been proposed that these forests have a significant biogeophysical effect on annual mean global temperature. Symbols display main environmental and socio-economic drivers. See Supporting Information (1) for details including references.

2.2. Different finance modes of importance for mapping links between the biosphere and financial sectors

Financial actors contribute to biome modifications by financing the extractive activities of companies. Financing generally occurs through a combination of loans and bonds, and through stock (also known as

equity), where stocks are issued either through an initial public offering or so-called seasoned offerings (Mayer, 1990; Rajan and Zingales, 1995; Booth et al., 2001). Hence both equity and debt are important for understanding the links between financial actors and our focal biomes.

However, from a finance perspective, there is a fundamental difference between stocks, and bonds and loans. Bonds and loans relate to a usually fixed claim on part of the revenues of a project or firm. With debt, financiers can reveal their preference with origination: they may withhold capital from environmental laggards, thus signaling discontent and pushing down prices. Financiers may also include covenants in the debt contract relating to environmental performance. Violation of a covenant may trigger default. Stock on the other hand, holds a residual claim on the firms' profits and has ownership rights allowing stockholders to vote about strategic decisions of the firm and the appointment of top executives. As such, the role of stock is more prominent than that of other types of finance in the governance of the firm (Edmans, 2014). In addition, stock ownership also determines the potential degree to which any one investor has influence over corporate decisions, operations, and thus strategic development (Appel et al., 2016).

There are three main mechanisms by which influence can be achieved by shareholders: *voting* (or proxy voting in the case of investment managers, Dam and Scholtens, 2013); *direct engagement* with management, either informally or through systematic engagement (Dimson et al., 2015); and *divestment* (or the threat of it), which may push stock prices down and signal discontent by investors with the corporate governance of the firm (Edmans, 2014).

Mapping the ownership of financial assets in firms, the capital flows from financial actors to companies, and the specific economic activities of firms on the ground is not straightforward due to severe limits in the availability of financial data. While data on shareholders is freely available for publicly listed companies, data on loans is not generally easily accessible due to the opacity of banks' balance sheets, especially their loans section. Ownership of private firms is in addition highly opaque (Morgan, 2002; Flannery et al., 2004; Stiroh, 2006). Limited access to financial data is not a problem exclusively for our analysis, but an issue for studies in this domain in general (Galaz et al., 2018).

Given the limited accessibility of detailed debt data, and the influence associated with stock ownership, our main analysis uses equity data and maps the ownership of financial actors in key corporations that currently affect the social-ecological dynamics of our focal biomes. We also assess the sensitivity of the firms to financiers by calculating the debt to capital ratio for all companies in our sample, and compare them to industry-wide averages (Damodaran, 2017).

It should be noted that market structure, financing of corporate operations, and a firm's influence on key drivers of change of tipping elements, can differ considerably depending on the sector and the country of interest. Table 1 summarizes the corporate structure in the selected biomes, and shows the level of concentration in each sector, across both publicly listed companies and in private and other companies (see Supporting Information 2 and 3, as well as tables S1 and S2 for limitations, detailed data and information about available data depending on company type). Table 1 shows that concentration is high in all four sectors and motivates our focus on the major owners of the dominant companies operating in the biomes elaborated below.

2.3. Data analysis

To assess linkages between financial systems and tipping elements in a systematic way, we develop an interdisciplinary and exploratory methodology that combines insights from the Earth system and sustainability sciences with corporate finance. The details, as well as limitations, can be found in Supporting Information (2), and include five steps: a) identification of the main proximate drivers of land-use change in each biome (*sensu* Geist and Lambin, 2002); b) identification of the most important industrial sectors associated with these drivers in the selected biomes; c) identification of the largest companies in each sector in terms of market share; d) data analysis of the ownership in selected strategic companies; and e) identification of the prevalent stockholders, that is, financial actors with ownership in at least one company operating in each of the selected biomes and sectors linked to tipping elements.

The selection of companies in c) is based on their market share in the sector of interest only, without incorporating any company-specific environmental assessment. Several of the companies in our analysis have deforestation policies in place, but are included by virtue of their size and market dominance. By being vertically integrated and by providing enhanced market access to a vast amount of producers (particularly in Brazil), we argue that selected companies can influence the rest of the supply chain, as well as have spill-over effects on market competitors. The chosen forestry companies in Canada and Russia control a large landbank and represent a substantial revenue share in the sector, therefore making their forest management policies crucial to forest degradation and forest cover loss.

As we elaborate below, the stockholders identified in e) can influence drivers of environmental change in multiple regions at the same time. Through their investments policies or engagement strategies they could therefore *in principle* affect multiple known tipping elements simultaneously.

Analysis of ownership is based on data from the *Orbis* database which contains information on over 200 million companies worldwide (Bureau, 2017). Note that identification of prevalent stockholders is only possible for listed companies and private companies with known owners. For several private companies in our selection (7 out of 29 companies), no information about shareholders is available through databases like *Orbis*. We calculate the debt ratio as the book value of debt (both long-term and short-term), divided by total book value of debt and shareholders' equity (based on Damodaran, 2017). For detailed information on calculations and full list of company ratios, see Supporting Information (5).

3. Results and discussion

3.1. "Prevalent stockholders": who are they and why are they important?

Large financial actors have been shown to possess significant corporate control globally (Vitali et al., 2011; Fichtner et al., 2017). Until now, however, such control has not been linked to changes in biomes associated with tipping dynamics in the Earth's climate system. Table 2 lists what we denote as prevalent stockholders, and estimates of their "blockholding" power in key companies operating in each selected

Table 1
Market share held by the top 4 publicly listed and the top 4 private and other companies in each sector (%).

Sector	Top 4 publicly listed companies	Top 4 private and other companies	Sum of the top 4 public and top 4 non-public companies
Brazil, Beef	70.4%	10.7%	81.0%
Brazil, Soy	29.0%	32.0%	60.9%
Canada, Wood, pulp and paper	23.4%	12.1%	35.5%
Russia, Wood, pulp and paper	21.3%	45.6%	66.9%

Note: The table is based on data from the top 100 companies in each sector (top 50 in Russia). 'Private and other' include private companies, state-owned companies, cooperatives, First Nations, and similar. See Supporting Information (3) for details.

Table 2
List of financial institutions with ownership in the selected companies in all selected regions and sectors.

Nr	Stockholder	Location of headquarters	Category of stockholder	Ownership breadth[a]	Number of holdings ≥5%	Size of ownership[b] (million USD)
1	BlackRock	United States of America	Investment management firm	18	7	8,076
2	Vanguard	United States of America	Investment management firm/Mutual funds	18	6	6,853
3	Norway (via Norges Bank Investment Management)[c]	Norway	State/Bank/Pension fund/Sovereign wealth fund	18	0	2,193
4	Dimensional Fund Advisors	United States of America	Investment management firm/Mutual funds	17	0	1,151
5	Credit Suisse	Switzerland	Bank/Investment management firm	12	1	422
6	Bank of New York Mellon	United States of America	Investment management firm/Bank	12	0	1,188
7	State Street	United States of America	Investment management firm/Bank	11	2	4,804
8	AXA	France	Insurance/Investment management firm	10	1	890
9	JPMorgan Chase & Co	United States of America	Bank/Investment management firm	10	0	1,123
10	Principal Financial	United States of America	Investment management firm	10	0	402
11	Deutsche Bank	Germany	Bank/Investment management firm	10	0	356
12	Fidelity Management & Research	United States of America	Investment management firm/Mutual funds	9	3	3,200
13	Stichting Pensioenfonds ABP (National Civil Pension Fund)	The Netherlands	Pension fund	9	0	646
14	Franklin Templeton Investments	United States of America	Investment management firm	5	0	1,641
15	Van Eck	United States of America	Investment management firm	5	0	337
16	Russell Investments	United States of America	Investment management firm	5	0	93

Note: [a]Ownership breadth is defined as the number of companies a stockholder has investments in (Fichtner et al., 2017), out of the 29 companies studied. [b]Size of ownership is calculated as the product between the market capitalization of the listed company and the percentage of shares directly or indirectly owned by the stockholder. [c]Norges Bank Investment Management is the unit of the Central Bank of Norway which manages the Government Pension Fund Global on behalf of the Ministry of Finance of Norway.

biome associated with a tipping element (see Supporting Information 4 for more details). We label these owners as "Financial Giants" because of their size and potential to influence companies. They are ranked according to the number of companies in which they own shares, here denoted "ownership breadth" (see Fichtner et al., 2017). Blockholding generally refers to shareholding of at least 5% (Edmans, 2014), and is in the finance literature generally assumed to entail considerable influence over corporate governance.

As our data show, these prevalent stockholders include a variety of financial actors ranging from international banks to institutional investors such as insurance companies, asset managers, and pension funds. All prevalent stockholders in Table 2 have shares in five or more of the selected companies. Six have individual blockholdings (≥ 5% of the shares) in at least one company. Two thirds are based in the US, including five of the top seven actors (in terms of ownership breadth).

Stockholders can coordinate their voting on issues related to corporate control (elaborated below). Therefore, it is also interesting to assess these actors' aggregated influence in each of the selected biomes. In Fig. 2, we choose a 10% ownership level to indicate considerable voice in corporate governance that could be mobilized by these actors. This is the level usually applied to identify so-called "insiders" in the US corporate context. We also calculate the aggregated ownership of different coalitions based on possible patterns of potential collaboration between stockholders (elaborated below).

Our analysis shows that the largest passive asset managers in the world, the "Big Three" (*BlackRock*, *Vanguard* and *State Street*) together hold stocks above the 10%-threshold in 2 of 8 companies in the Amazon biome, 2 out of 16 in Canada's boreal forests, and 3 of 5 in Russia's boreal forests. The "Big Three" are known to collectively represent the largest corporate stockholders in the US (Fichtner et al., 2017), but their ownership has never before been linked to their influence on climate stability.

The 16 identified prevalent stockholders have an even larger aggregate potential influence. Findings indicate that these reach above the 10%-threshold in 3 of 8 companies in the Amazon, 5 of 16 in Canadian boreal forests, and 3 of 5 in Russian boreal forests. In seven of the 29 companies, the prevalent stockholders collectively represent the largest single stockholder.

A complementary measure of their influence relates to the concentration of equity ownership in each of the selected companies. High concentrations of equity ownership (in this case a high value on the Herfindahl-Hirschman index) also indicates the latent influence of equity owners. As Table 3 shows, such concentration is substantial for companies in the beef sector in Brazil, for economic activities in boreal forests in Canada and partly also in Russia (see also Supporting Information 4).

Fig. 2 and Table 3 thus show that as a collective, the "Financial Giants", through their common blockholding power, have a previously ignored, yet considerable potential influence in companies shaping biomes critical for the stability of the climate system.

3.2. Complementary mechanisms for influence

The previous section focused on equity as a means for the financial sector to exert influence over the fate of known tipping elements. Influence associated with ownership is, however, only attainable in listed companies. To what extent ownership influence alone is able to also translate into impacts on the sector as a whole, depends to a large extent on the composition of listed and non-listed companies, with the latter being more dependent on alternative funding. As mentioned above, debt is an important alternative financing mechanism for companies. However, debtholders lack control rights and have fewer means to influence corporate strategy (apart from including covenants in the contracts).

Table 4 shows the total book debt to capital of the selected companies, presented per sector and compared to industry averages. All our

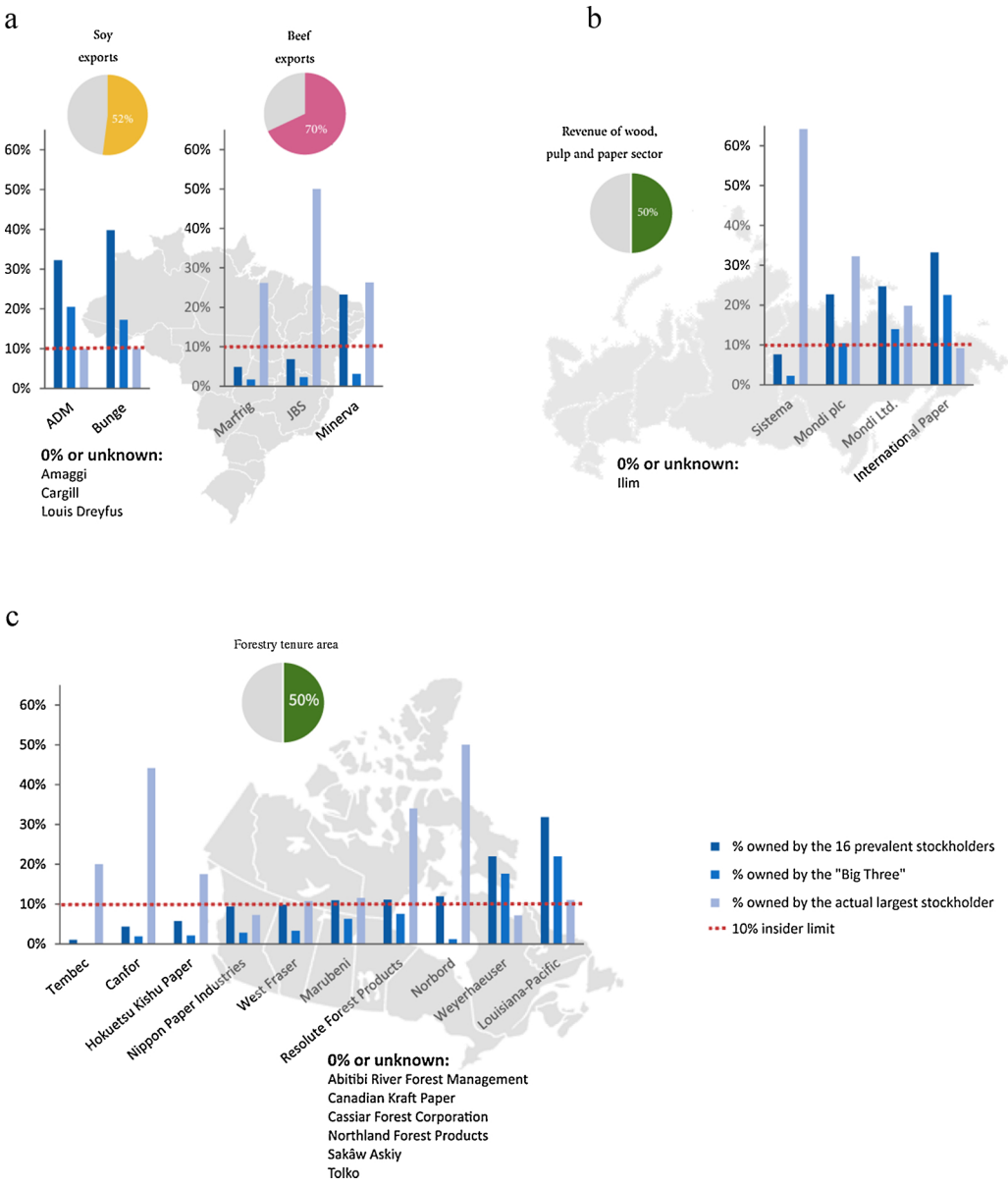

Fig. 2. Total ownership by the 16 prevalent stockholders in selected companies.
(a) Brazil, soy and beef sectors. (b) Russia, wood, pulp and paper sector. (c) Canada, wood, pulp and paper sector.
Fig. 2 shows the percentage of stock ownership of prevalent stockholders, the "Big Three" (BlackRock, Vanguard, and State Street) and the largest stockholder in each company (bar charts). For each sector, it also shows the total market share controlled by selected companies (pie charts). See Supporting Information (2) for methodological details.

focal companies in the beef sector rely heavily on debt. In the Canadian forestry sector a few companies (4) rely heavily on debt (see Supporting Information 5 and Table S3 for details). The debt ratio in the four sectors studied does not differ that much from global industry averages, as there is much variation in these figures (Damodaran, 2017; Appel et al., 2016).

In summary, the influence of "Financial Giants" on companies is considerable, but the extent differs depending on sector, and where in the world companies operate. The investors' latent influence is largest in the beef and soy sectors associated with economic activities modifying the Amazon tipping element, but the influence of the "Financial Giants" is still substantive in the other industries and regions. All four sectors show relatively high concentration and dominant power in their respective market, and are sensitive to external financing. Further, there is concentrated ownership of equity in the firms operating in each sector. As such, we conclude that the "Financial Giants" have the potential to influence corporate strategy in the Amazon and boreal forests.

3.3. Financial Giants – influence over climate stability and transformation

Despite limitations in available financial data, our methodology allows us to identify key financial actors with influence over economic activities modifying biomes associated with tipping elements in the Earth's climate system. The specific stockholders listed are naturally related to the selection criteria imposed here, but the interesting issue is the concept (and existence) of prevalent stockholders with the hitherto unrealized influence on such tipping elements. While several of the prevalent stockholders identified have indeed publicly acknowledged climate-related risks, we argue that their substantial ownership in industries that impact on key biomes and Earth system tipping elements, suggests they "punch below their weight" with regards to the

Table 3
Concentration of equity ownership in each publicly listed company, measured by the Herfindahl-Hirschman index (HHI).

Sector	Company	HHI	Average HHI per sector
Brazil, Beef	JBS	4938	2546
	Marfrig	1221	
	Minerva	1478	
Brazil, Soy	Archer Daniels Midland	292	345
	Bunge	398	
Canada, Wood pulp and paper	Canfor	2904	1021
	Hokuetsu Kishu Paper	542	
	Louisiana-Pacific	384	
	Marubeni	308	
	Nippon Paper Industries	204	
	Norbord	2640	
	Resolute Forest Products	1415	
	Tembec	1428	
	West Fraser	192	
	Weyerhaeuser	195	
Russia, Wood pulp and paper	International Paper	306	2133
	Mondi Ltd.	1308	
	Mondi plc	1652	
	Sistema	5265	

Note: The HHI index is computed as the sum of squared ownership (in %). Its theoretical maximum is 10,000 (monopoly), and its theoretical minimum approaches zero (pure competition) (Rhoades, 1993). Note that only shareholders with shares of at least 0.01% appear in our data.

promotion of corporate governance that bolsters the resilience of these biomes.

The degree to which the collective influence of the "Financial Giants" can be used in favor of climate stability is an issue deserving more attention by scholars interested in exploring the role of financial systems and actors for sustainability. However, a number of possible factors could be seen as barriers to an influence of this sort.

The first is the comparatively marginal economic role the ownership in these companies play for the portfolios of the identified prevalent stockholders. As an example, while investments of one of the largest asset managers (#1 in Table 2) in the selected biomes and economic sectors are considerable (we estimate them to be USD 8 billion), they represent only a fraction (< 0,01%) of the total assets under management by this investor, estimated to be of a total value of USD 5.1 trillion (BlackRock, 2017). Furthermore, several actors in Table 2 (#1, #2, and #7, the "Big Three") are commonly referred to as *passive investors*. These are investors who provide investment vehicles that track a market index or a specific market segment, activities which do not rely on active investment, such as voting and engaging. These investors not only invest on behalf of their clients (such as pension funds), but are also often assumed to lack incentives for exercising influence over individual companies, due to associated costs. In addition, coordination problems and free-rider dynamics can arise when the number of blockholders in any one company increases, decreasing individual incentives to act (Dam and Scholtens, 2013; Edmans, 2014). Together, this would imply that the identified financial actors might lack incentives to engage actively.

However, there are two reasons to believe the influence of identified prevalent stockholders is both considerable and possible. First, blockholders are, as already noted, generally considered influential. Despite the fact that most passive investors are characterized by investing small amounts in a multitude of companies to diversify risk, Fichtner et al. (2017) show that several of the largest investment firms in the US (including the "Big Three") are taking active steps toward more centralized stewardship and governance processes among their funds, which will allow them to maximize their voting power across all discretionary holdings. By pooling their funds' votes, the "Big Three" have been shown to vote against, and win over, short- and medium-term oriented investors at critical moments of decision-making (Appel et al., 2016; McCahery et al., 2016; Fichtner et al., 2017). Interestingly, recent analysis of the voting behavior of the "Big Three" show that these global investors tend to vote against proposals related to Environmental, Social and Governance (ESG) issues proposed by activist shareholders (Fichtner et al., 2017, pp. 21).

Second, institutional investors are expected to vote as part of their fiduciary duty to counterbalance the power of company management. While fiduciary duty has most often been interpreted by investors as seeking maximum financial returns on investments for their beneficiaries, there is a growing perception that the fiduciary duties of institutional investors should include sustainability considerations, even though it remains a contested position (EU High-Level Expert Group on Sustainable Finance, 2018). Actors such as pension funds and asset managers also invest for the long term, and at least some of the large investors are recognizing both their influence and their responsibility (Fichtner et al., 2017). As several scholars have noted, such investments in improved Environmental, Social and Governance criteria (ESG) may also have financial benefits, thereby providing further incentives for engagement from the side of stockholders (Margolis and Walsh, 2003; Orlitzky et al., 2003; Dimson et al., 2015; van et al., 2016).

4. Next steps

Financial actors, ownership and flows play a key role in the global economy. Through their influence over economic activities that modify biomes associated with tipping elements, financial actors can also affect climate stability. Our analysis shows that a subset of the global financial community plays a particularly important role in this regard.

These insights are of relevance to scholars, financial actors and policy makers. First, we bring to light the key role of large international institutional investors. Their behavior and influence, as major

Table 4
Total book debt to capital of all selected companies, presented per sector and compared to industry averages (2016).

Sector	Book debt to capital	Industry total book debt to capital (Damodaran, 2017)	
Beef Brazil	73.7%	Food processing, Emerging markets	40.1%
Soy Brazil	25.4%	Farming/Agriculture, Global	49.1%
Wood, pulp and paper Canada	56.5%	Paper/Forest Products, Global	45.6%
Wood, pulp and paper Russia	53.9%	Paper/Forest Products, Global	45.6%

Note: The total book debt to capital ratio is calculated as the ratio between the book value of long-term and short-term debt and the sum between book value of long-term and short-term debt and the book value of shareholders' equity, following the methodology adopted by Damodaran (2017). See Supporting Information (5) for details.

blockholders in companies linked to economic activities shaping ecosystems all over the world, have yet to be studied in depth. Second, the approach and results presented here can provide further impetus for research on how global actors, distant drivers and "telecouplings" affect the climate system and the biosphere (Liu et al., 2015; Österblom et al., 2015; Scholtens, 2017).

The methodology presented here could be applied to other economic sectors to link companies and investors to other important biosphere functions. Such analyses could, and should, be complemented with other financial data. Mapping the links between financial actors and critical tipping elements in the climate and the broader Earth system opens up a range of new and important questions. Can fiduciary duty include damages to global environmental commons, affecting millions of people for generations to come? How large are the material risks associated with non-linear changes in these critical biomes, including their climate repercussions? What economic, political and social pressures shape the investment and corporate engagement behavior of "Financial Giants"? And does their voting behavior and ownership engagement differ across sectors, including those associated with biomes critical for alternative trajectories of the Earth system (Steffen et al., 2018)?

Questions such as these require increased attention as scholars, financial institutions, policy-makers and civil society move forward to address the risks entailed with rapid global environmental change.

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Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at https://doi.org/10.1016/j.gloenvcha.2018.09.008.

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